Causal chain analysis

This section aims to identify the root causes of the environmental and socio-economic impacts resulting from those issues and concerns that were prioritised during the assessment, so that appropriate policy interventions can be developed and focused where they will yield the greatest benefits for the region. In order to achieve this aim, the analysis involves a step-by-step process that identifies the most important causal links between the environmental and socio-economic impacts, their immediate causes, the human activities and economic sectors responsible and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis also recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. In order to ensure that the final outcomes of the GIWA are viable options for future remediation, the Causal chain analyses of the GIWA adopt relatively simple and practical analytical models and focus on specific sites within the region. For further details, please refer to the chapter describing the GIWA methodology.

Of the four transboundary lakes in the East African Rift Valley Lakes GIWA region that have been the subjects of this assessment, the Lake Victoria Basin (LVB) faces the most complex social, economic, political and technical barriers (Duda 2002). The environmental degradation of Lake Victoria Basin over the last three decades, due to unsustainable use of natural resources, massive algal blooms, water-borne diseases, water hyacinth infestation, oxygen depletion, introduction of alien fish species etc., has been determined as placing a present value of 270-520 million USD at risk to the lake communities if the large export fishery for Nile perch is lost (World Bank 1996). Alarm over the accelerated degradation was the key driving force in the Lake Victoria GEF project being approved in the mid-1990s as the then largest GEF international waters project at 77 million USD (Duda 2002). At about the same time, the Lake Victoria Fisheries Organisation (LVFO) was formed by Kenya, Uganda and Tanzania under the Convention of Fisheries. The Lake Victoria five-year GEF project was the first of several intended interventions over time (Duda 2002).

Given the intertwined diverse issues and complexities that have all contributed to the environmental degradation of its Basin, as well as the interventions that have been initiated in order to address and mitigate the environmental degradation, the Lake Victoria Basin stands out as the prime choice for Causal chain and Policy options analyses. Because of the similarity of environmental problems affecting the East African Great Lakes, as well as similarities in the socio-political, economic and health status of the various riparian countries, the Lake Victoria Causal chain and Policy options analyses that are presented in this report were considered to be highly applicable to the rest of the region.

Methodology

The priority concerns established from the GIWA assessment that was carried out for Lake Victoria were Unsustainable exploitation of fish and other living resources and Pollution. The major environmental issues and their relative contributions (in % terms) to environmental degradation were also identified from the assessment (Table 19 and 24). For Unsustainable exploitation of living resources, the priority issues that were identified were overexploitation, and destructive fishing practices. For Pollution, the priority issues that were identified were microbiological, eutrophication, chemical and suspended solids. Given the complex interactions, synergistic and cumulative effects of the factors contributing to pollution, it is difficult to clearly and unambiguously isolate only one or two of the issues as predominantly causing pollution in Lake Victoria. All four issues identified from the assessment are considered in the Causal chain analysis, but the role

of suspended solids as a pollutant is considered to be nested within the other three issues, exacting a synergistic and cumulative effect on microbiological, eutrophication and chemical pollution.

A detailed assessment was carried out in order to determine the immediate causes, sectors/activities and root causes that related to the priority issues. The data assembled enabled the prioritising of the immediate causes according to criteria such as: 1) the transboundary nature; (2) the size of geographical area affected and whether it is widespread or localised; (3) the number of people affected including their livelihoods and health; (4) the sectors that are affected and the degree of impact; (5) community benefits derived from the environmental resources vis-à-vis costs of negative environmental impacts arising from the use of the resources; (6) the duration and degree of severity of the environmental impacts; (7) effectiveness of current structures, controls, institutions and legislation in minimising negative environmental effects; and (8) synergistic and cumulative effects. Some of the hypotheses raised are provided in Annex III. More weight was given to issues for which there was recent and quantitative data than for those which are as yet poorly studied and lack quantitative data.

Unsustainable exploitation of fish and other living resources

The important GIWA issues identified for Unsustainable exploitation of living resources were overexploitation and destructive fishing practices (Table 19).

Table 19 Unsustainable exploitation of fish in Lake Victoria: percentage contribution of issues and immediate causes of the impacts.

Issue	%	Immediate cause	%
*Overexploitation	30	Increased effort	60
		Technological change	40
Excessive by-catch and discards	20		
*Destructive fishing practices	30	Increased effort	40
		Rent-seeking behaviour	30
		Failure of monitoring and enforcement mechanisms	30
Decreased viability of stock through pollution and disease	10		
Impact on biological and genetic diversity	10		

**Issues considered relevant for Causal chain and Policy options analysis.*

Overexploitation

Immediate causes

Overexploitation is mainly due to increased effort (Figure 24). An experimental trawl Catch Per Unit Effort (CPUE) shows a continuous and significant decline since trawling research began in 1969 (Uganda): CPUE in waters less than 30 m deep averaged 797 kg/hour during the 1961–1971 surveys and declined to 115 kg/hour in the 1997–1998 surveys (Okaronon, 1999) (Figure 25). The apparent decline in fish stocks can only partially be attributed to change in species composition, and different behaviour and possibly net avoidance of the species presently targeted by the trawl (Okaronon 1999). The fishing capacity in the Uganda sector increased from about 3 200 fishing canoes in 1972 to 8 000 by 1990 and was estimated to be about 10 000 canoes in 1998 (Okaronon 1999). The number of fishermen in Lake Victoria increased from 83 816 in

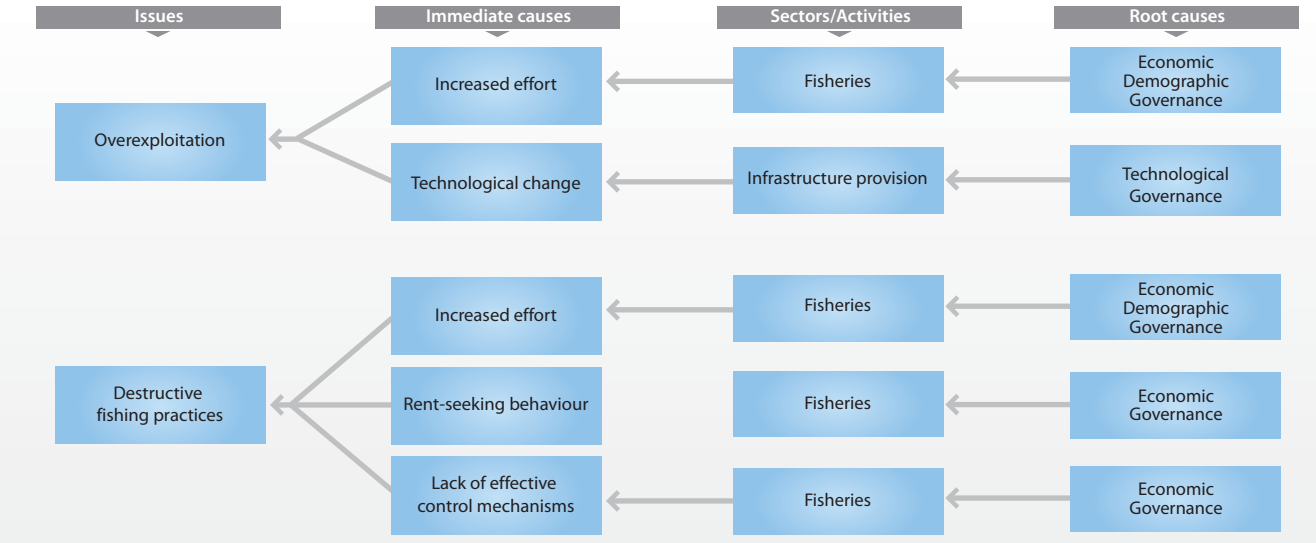


Figure 24 Causal chain diagram illustrating the causal links for Unsustainable exploitation of fish and other living resources.

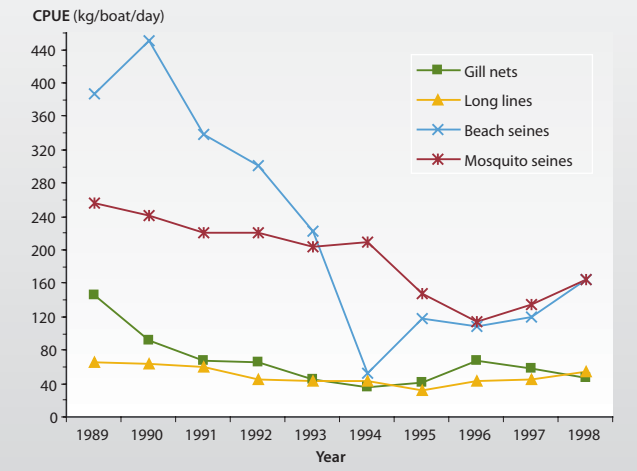
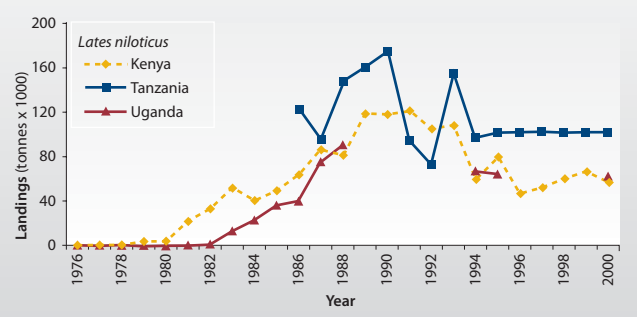
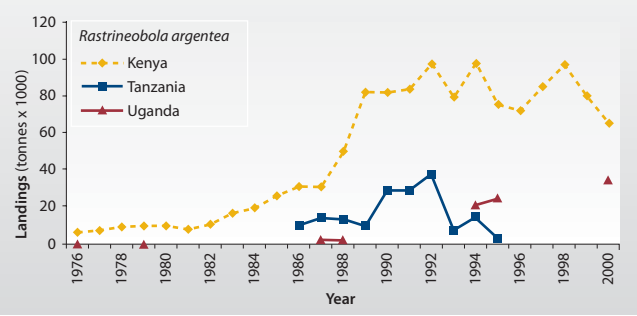


Figure 25 Trends in catch per unit effort for Nile perch in commercial fisheries of Lake Victoria.
(Source: Okaronon 1999, Othina 1999 in Bwathondi et al. 2001)





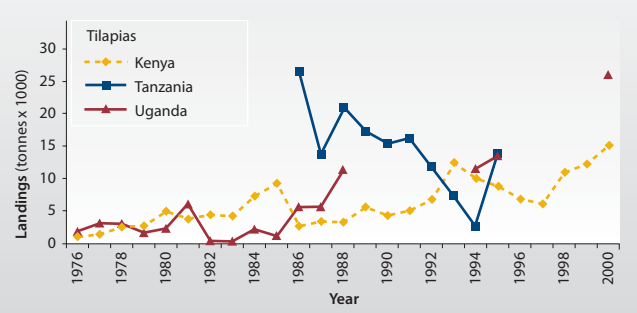


Figure 26 Trends in landings of the major commercial fish species in the riparian countries of Lake Victoria
(Source: Knaap et al. 2002)

1990/1991 to 121 941 in 2000. In Kenya the fishermen increased from 24 000 to 33 037, in Uganda the increase was from 30 000 to 32 461 while in Tanzania the fishermen increased from 29 816 to 56 443 over the same period (Hoekstra et al. 1991, Asila 2001). The increases in the number of fishermen in Uganda (~8%) appear to be minimal compared the increases in Tanzania (~90%) and Kenya (~38%).

For the 1990s, data on the fishery yield for Uganda are fragmented, and poor quality catch assessment data have prevented any evaluation of trends in Tanzania (Bwathondi et al. 2001). The increase in fishing effort and investment (Uganda) was made without clear knowledge of the magnitude and sustainability of the stocks (Okaronon 1999). Trends in fish landings in Kenyan waters of Lake Victoria (1976–1988) show that landings reached a maximum of 200 000 tonnes per year in 1989–1991 as Nile perch catches increased due to an expansion in stock size and increased fishing effort (Othina 1999). CPUE peaked at 180 kg/boat/day in 1989 and decreased thereafter with increasing effort (Othina 1999). With increased fishing pressure, predation, and competition among species, the multispecies fishery of Lake Victoria changed to only three species: Nile perch (*Lates niloticus*), the pelagic cyprinid-dagaa (*Rastrineobola argentea* Pellegrin), and the introduced tilapia (*Oreochromis niloticus* L.) (Figure 26). By 1998, total Nile perch catches were half those at the beginning of the decade despite increased effort, and catches of *Rastrineobola argentea* have also levelled off despite increased effort (Othina 1999).

Bottom trawl surveys in Kenyan waters of Lake Victoria (1997-1998) revealed that areas with relatively consistent high catches extend from west of Maboko Island up to Mbita Channel in the depth range of 5-22 m (Getabu and Nyaundi 1999). This area is outside major urban and riverine influence and is where most of the fishing effort by artisanal fishermen is currently concentrated (Getabu and Nyaundi 1999). Despite increased total fishing effort, efficiency of fishing gear and extension of fishing grounds to maintain the yield, there has been a progressive decline in CPUE and mean size of fish caught (Ligtvoet & Mkumbo 1992, Mkumbo & Cowx 1999). In all three countries, efforts in terms of boats and numbers of fishermen have more than doubled in the past 10 years (Namisi 2001, Asila 2001). The unrestricted access status of the Lake and lack of enforcement of existing legislation is linked to increasing and crippling fishing effort (Bwathondi et al. 2001).

Overexploitation is secondarily due to technological changes in the efficiency of fishing gears, motorisation of canoes and increase in total fishing effort to maintain production since the mid-1990s (Bwathondi et al. 2001). Most of the region's factories suffer from fish supply problems, attributed to low catches and competition with other fish factories

(SEDAWOG 1999) and, in order to stay operational, they drive fishermen to catch more fish by supplying nets, outboard engines, etc.

Sectors/activities

Increased effort has been driven by a much greater demand for fish by recently established fish processing factories that have a large capacity for processed products (Abila 2002). Nile perch fisheries opened up greater employment opportunities, attracting more fishers (artisanal to large-scale), more fishing gear and vessels to access the resource, and the establishment of fish filleting factories (Bwathondi et al. 2001). Industrial fish processors in Uganda are presently the main link between the artisanal fisherfolk and the overseas export markets; their entry into the market has tended to stabilise and expand the market for the artisanal fisherfolk while increasing their average earnings (Namisi 2001). Dwindling fish stocks are necessitating increased effort in order to maintain the same level of catch (Kulindwa 2001). In other words, resource rents are being reduced over time until the increase in fishing effort will no longer be beneficial.

Technological change has come about mainly due to demand for higher fish catches to supply the fish processing factories and consequently the huge export market (Table 20). A number of fish processing plants have been constructed along the shores of the Lake, 11 of which are licensed to operate in the Uganda sector of the Lake (Odongkara & Okaronon 1999), 12 in Kenya and 12 in Tanzania (Ntiba 2003). The large number of processing factories, whose capacity is about 120 000 tonnes per year (Table 21) versus the total landings for the Lake being in the region of 210 000 tonnes, is an important driver of exploitation of the fishery. Nile perch is purchased and processed mainly by the large-scale processors (Bwathondi et al. 2001).

Table 20 Export quantities for Nile perch fillets between 1988 and 1999.

Year	Kenya (tonnes)	Uganda (tonnes)	Tanzania (tonnes)
1988	ND	ND	37
1989	ND	18 347	ND
1990	4 350	1 590	ND
1991	6 364	4 751	ND
1992	11 312	7 831	9 850
1993	8 189	6 337	6 123
1994	9 439	6 564	8 454
1995	10 983	12 971	9 904
1996	16 472	16 397	15 000
1997	11 167	9 839	ND
1998	10 126	13 755	ND
1999	9 765	ND	ND

Note: ND = No Data.

(Source: Fisheries Department 1950, Gibbon 1997, Department of Fisheries Kenya, Unpublished LVFO data, from Bwathondi et al. 2001)

Of the factories currently operating in the region, the majority commenced operations after 1990, an indication of the region's relatively recent entry into the global fish market (SEDAWOG 1999). Fifteen out of 25 factories surveyed in the region have been obliged to close down at least once during 1997/1998 to carry out modifications so as to comply with EU import regulations (SEDAWOG 1999). Many of the fish processed are small-sized because demand from export markets is for small fillets, which are less fatty and portion-sized (Bwathondi et al. 2001).

The establishment of the Dutch Government-sponsored Fish Meal Plant in Mwanza (Tanzania) in the 1970s contributed substantially to the decline of the haplochromines in the Lake since the factory targeted this fish group (Bwathondi et al. 2001). The decline of fish catches over time has also necessitated the use of illegal degrading technologies in order to catch more fish (Kulindwa 2001, Abila 2002).

Root causes

The high demand for processed fish products is driven mainly by the large export market for Nile perch fillets that emerged in the early 1990s (Kulindwa & Mbelle 2002, Kulindwa 2000, Abila 2002). Increasing population within the Basin, poor governance in the fishing industry, and the unrestricted access status of the Lake are secondary drivers (Table 22). The large export fishery for the Nile perch is estimated at 270-520 million USD (Duda 2002). Fishers annual incomes (per capita) are estimated as follows: Kenya, 3 269 USD; Tanzania, 2 294 USD; and Uganda, 1 157 USD (Bwathondi et al. 2001). The gap between the richest and poorest fishers in some beaches is widening, and the gap between the benefits obtained from the fishery by vessel owners and labouring classes is also widening (Bwathondi et al., 2001). Due to high demand for Nile perch (both export and local markets), processors are providing loans to some fishers who then repatriate the outlays through catches to the companies (SEDAWOG 1999, Bwathondi et al. 2001). The scarcity of fish has increased fish prices at the landing sites (Bwathondi et al. 2001). Thus rich firms are able to displace less rich processors, some of whom have been forced to close down: this has led to serious impacts in the fisheries sector and has intensified the existing conflicts between users (Yongo 2000). By-products from the factories are numerous and include skins, off-cuts ('chips'), swim bladders and carcasses ('frames'). Swim bladders are the most valuable and are exported to the Far East (SEDAWOG 1999).

Table 21 Capacity of fish processing factories, annual landings, and maximum sustainable yield for the three riparian countries in 1999.

Country	Full capacity (tonnes)	Used capacity (%)	Annual landings (tonnes)	Maximum sustainable yield (tonnes)
Kenya	35 260	49	64 000	39 200
Tanzania	104 520	69	95 000	98 500
Uganda	74 100	45	72 632	75 500

(Source: Bwathondi et al. 2001)

Table 22 Summary of the processes and actions behind the root causes of overexploitation of fish.

Root causes	Sectors/ Activities	Immediate causes	Remarks
Economic	Fisheries	Increased effort	1. Export markets. The processing industries are geared to export markets which have a high demand for fish and fish by-products and at higher cost per kg than local markets. 2. Poverty. The rich (processing factories) provide loans to the poor (artisanal fishers) to increase the catch for fish processing factories so that they can operate at optimal capacity to service the export markets. 3. Lack of alternative economic activities for sustenance of livelihoods. Nile perch fishery opened up greater employment opportunities.
Demographic	Fisheries	Increased effort	1. In all three countries, efforts in terms of boats and numbers of fishermen have more than doubled in the past 10 years, partly as a result of demand from export markets, but also due to the very rapid population growth and consequently higher demand for fish food in the region.
Governance	Fisheries	Increased effort	1. The Lake has an unrestricted access status. 2. There are lack of rules and regulations, such as fishing quotas, to govern the fisheries sector. 3. Bans on certain types of fishing gears and trawlers have been imposed in all three countries but there is lack of enforcement by government officials. 4. Lack of taxes or other form of finance to support enforcement of regulations in fisheries sector
	Infrastructure provision	Technological change	1. Increased number of fish processing factories have been established and licensed to operate without regard to sustainability of the fisheries resource (in all three countries) 2. Operations and of fish processing factories have become more efficient to comply with EU import regulations. 3. Fish processing factories are located close to major roads and airports, while motorised canoes and trawlers reduce time taken to access fish landings and offload fish.
Technological	Infrastructure provision	Technological change	1. Technological change (more fishing gear, vessels) is driven mainly by demand for higher fish catches to supply the processing factories and consequently the huge export market. 2. Change in the efficiency of fishing gears, motorisation of canoes have contributed to the signs of decline of the Nile perch since the mid 1990s.

The marketing of Lake Victoria's fish was localised within the riparian states during the pre-Nile perch era, but as most fish filleting factories were established in the 1990s, both the regional and international trade expanded (Bwathondi et al. 2001, Kulindwa 2001, Abila 2002). The Nile perch is now sold not only to the traditional EU and Middle Eastern countries but also to Japan, Australia, North and South America (Bwathondi et al. 2001). The price ranges for fish products such as chilled fillets, frozen fillets, portions, head-on gutted fish, head-off gutted fish and kosher products is 2-4.5 USD per kilo (SEDAWOG 1999).

Destructive fishing practices

Immediate causes

Destructive fishing practices are due mainly to increased effort (Figure 24, Table 19). There has been a reduction in mesh size of nets used, and an increased proportion of immature fish in the catches (Bwathondi et al. 2001). Mesh sizes have progressively declined over the past 10 years with 24% of the nets (LVFO 2000, Kulindwa 2001) in Uganda now below the recommended mesh size of 5 inches (127 mm). More recent beach surveys suggest that this is now as high as 50% (Muhoozi cited in Bwathondi 2001). In Kenya and Tanzania, 3 and 18%, respectively, of the gillnets are below the legal mesh size limits (Bwathondi et al 2001). Trends (1987–1997) in percentage contribution by weight of the four major fishing gears to the Kenya Lake Victoria catches are as follows: mosquito seine landings increased from 25% of the total catch in 1987 to 50-60% from 1994 to 1997 (Kenya); the gillnet contribution declined from over 50% to 20%; the long-line contribution declined from 10% to 5%; while the beach seine contribution has increased from 10% to 20% despite a ban on their use (Figure 27) (Othina 1999, Kulindwa 2001, Abila 2002). Rent-seeking behaviour probably accounts for up to 20% of the contribution to destructive fishing practices. Beach seines and trawls, 10 of which were operating in Kenyan waters until recently (Njiru cited in Bwathondi et al. 2001), are banned gears in the Lake.

Reduced capacity to meet human needs can account for up to 40% of the destructive fishing practices. As traditional fishing methods are now often considered inadequate for landing a sufficient catch, fishermen

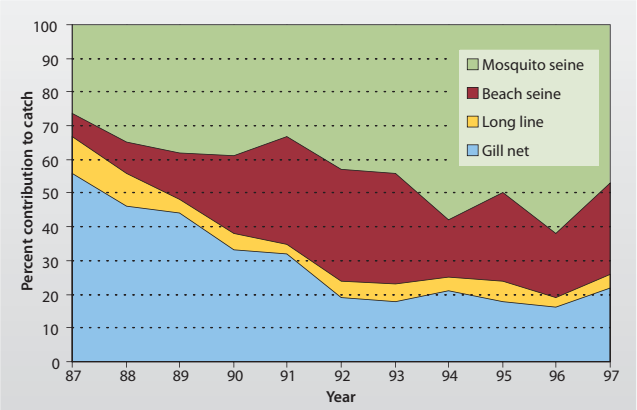


Figure 27 The percent contribution by weight of the four major fishing gears to the Kenyan Lake Victoria catches.
(Source: Othina 1999)

increasingly resort to deploying illegal fishing gear such as cast nets, fish poison and weirs to improve their catches (Ntiba 2003). Some of the gears used to fish are fallouts from other sectors such as the flower industry, where fine mesh nets that are used to protect flowers from birds are now being used. In a 1999 LVRFP study of 1 066 fishers in all three countries of the Lake, 33% of respondents linked declines in the stock to the contravention of fishing regulations, 32% felt this was due to excessive fishing effort and 11% to pollution or the presence of water hyacinth (SEDAWOG 2000). In most cases, these reasons provided for catch declines indicate a widespread acknowledgement amongst the Lake's fishing communities that effort levels are excessive, that damaging fishing techniques are in use and that regulations are generally ignored (Bwathondi et al. 2001).

Sectors/activities

Most of the region's factories suffer from fish supply problems, attributed to low catches and competition with other fish factories (SEDAWOG 1999). Due to the boom in the Nile perch export market, many more people who were never fishermen moved to cash in on the "lucrative" industry. This may have pushed traditional fishermen to resort to the use of destructive fishing methods to sustain their level of livelihood and food requirements. The use of poison, which led to a ban on fishing and the sale of fish in March 1999 (Ntiba 2003), was probably largely due to rent-seekers. The remoteness of some of the landing sites and the inadequate transportation infrastructure impose severe constraints on the post-harvest sector of the Lake Victoria fishery (Bwathondi et al. 2001). Handling facilities, ice plants, storage facilities, sanitary conditions (including boats with containers) are either lacking or inadequate at landing sites, contributing to poor fish quality (Bwathondi et al. 2001).

Root causes

The reduction of taxes on all nets has resulted in more net purchases. The increase in population has resulted in increased demand for fish (particularly tilapia) for local consumption. The unrestricted access status of the Lake and lack of enforcement of existing legislation is linked to increasing and crippling fishing effort (Bwathondi et al. 2001). There is also a lack of awareness amongst some of the fisherfolk on the mid- to long-term consequences of destructive fishing methods. The policy of free and unrestricted access to the Lake Victoria fisheries appears to be the major loophole that was exploited by the rent-seekers (Table 23). With the near disappearance of many food fish species (Mkumbo 1999) and signs of decline in Nile perch (Othina & Osewe-Odera cited in Mkumbo 1999), a number of management measures were effected, including a ban on beach seines and undersized mesh nets (<127 mm stretched mesh) in 1994, and a ban on trawlers in 1996 (Mkumbo

Table 23 Summary of the processes and actions behind the root causes of destructive fishing practices.

Root causes	Sectors/ Activities	Immediate cause	Remarks
Economic	Fisheries	Increased effort	1. Export markets. The high demand for fish and fish by-products coupled with dwindling stocks of Nile perch, tilapia and haplochromines has led to destructive fishing practices (illegal fishing gear, poison, weirs and trawling) in order to, at least, maintain the fish supply level. 2. The reduction of taxes on all nets has resulted in more net purchases. 3. Increased competition for fish supply amongst fish processing factories. 4. Poverty. The rich (processing factories) provide loans to the poor (artisanal fishers) to increase the catch for fish processing factories so that they can operate at optimal capacity to service the export markets.
	Fisheries	Rent-seeking behaviour	1. Some of the gear used to fish, i.e. fine mesh nets, are a fallout from other sectors such as the flower industry. 2. Theft (of fishing gears, vessels, etc.) and piracy are rampant on the Lake, and may become worse as the disparity in distribution of benefits from the fishery becomes more polarised. 3. Greed- individual interests take precedence over community interests.
	Fisheries	Lack of effective control mechanisms	1. As traditional fishing methods are now often considered inadequate for landing a sufficient catch, fishermen increasingly resort to deploying illegal fishing gear such as cast nets, fish poison and weirs to improve their catches. 2. Lack of resources in government to create new avenues for employment and improve livelihoods.
Demographic	Fisheries	Increased effort	1. The increase in population and increased settlements along the lake shore has resulted in increased demand for fish (particularly Tilapia) for local consumption, hence, for example, continued use of beach seining that has been banned in all three countries.
	Fisheries	Lack of effective control mechanisms	1. Entry of people from other sectors (e.g. horticultural) into the fisheries sector who do not heed the rules and regulations of the fisheries sector. 2. Political patronage.
Governance	Fisheries	Increased effort	1. The Lake has an unrestricted access status, and there is no recognition of property rights and entitlements. 2. There are lack of rules and regulations, such as fishing quotas, to govern the fisheries sector. 3. There is weak regional integration and poorly co-ordinated and disparate legal and institutional arrangements governing the fishing industry. 4. Bans on certain types of fishing gears, beach seining and trawlers have been imposed in all three countries (1994-1996) but there is lack of policing and enforcement by government officials. 5. There is a low level of civic education and awareness amongst some of the fisher-folk on the mid- to long-term consequences of destructive fishing methods.
	Fisheries	Rent-seeking behaviour	1. The policy of free and unrestricted access to the Lake Victoria fisheries appears to be the major loophole that was exploited by the rent-seekers. 2. Corruption is rampant – officials charged with monitoring and enforcement of rules and regulations in the fisheries sector are often bribed to overlook the contraventions. 3. There is a lack of institutional and legal capacity to promote compliance and enforce arrangements and policies. 4. There is inadequate integration of environmental considerations in planning and management. 5. Lack of stakeholder participation.
	Fisheries	Lack of effective control mechanisms	1. Inadequate legal and judicial framework. 2. Lack of co-ordination and co-operation between all stakeholders in the fisheries sector. 3. Inability of government and other stakeholders to control catch and cost of fish. 4. Lack of incorporation of stakeholders when drafting legislation.

1999). Failure in monitoring and enforcement of these bans is evident, for example, beach seining in Kenyan waters continues despite its ban. Overfishing and the use of damaging or illegal fishing gear is only in part a reflection of the failure of centralised management strategies on the Lake, and are symptomatic of broader social, economic and developmental dislocations (Bwathondi et al. 2001) such as poverty and lack of employment. Theft (of fishing gears, vessels, etc.) and piracy are rampant on the Lake, and may become worse as the disparity in distribution of benefits from the fishery becomes more polarised (Bwathondi et al. 2001).

Pollution

The following pollution issues: microbiological, eutrophication, chemical and suspended solids, were identified as being the most important (Table 24). It was noted that suspended solids are part and parcel of the factors that contribute to microbiological, eutrophication and chemical pollution, and that their role is more important in its synergies with the other three issues rather than on its own. Therefore, the issue suspended solids is nested within microbiological, eutrophication and chemical pollution and is excluded from direct further analysis.

Table 24 Pollution in Lake Victoria: percentage contribution of issues and immediate causes of the impacts.

Issue	%	Immediate cause	%
* Microbiological	20	Animal waste	10
		Municipal untreated effluent	40
		Run-off and stormwater	40
		Maritime transport waste	10
*Eutrophication	20	Enhanced effluent discharge	30
		Enhanced discharge of solids	10
		Run-off and stormwater	60
* Chemical	20	Enhanced effluent discharge	40
		Enhanced discharge of solids	20
		Run-off and stormwater	20
		Atmospheric deposition	20
*Suspended solids	20	Habitat modification	40
		Enhanced erosion of lake shore and river channels	30
		Increased sediment deposition	30
Solid wastes	10		
Thermal	0		
Radionuclide	0		
Spills	10		

**Issues considered relevant for Causal chain and Policy option analysis.*

Microbiological

Four immediate causes have been linked to microbiological pollution, namely: municipal untreated sewage, run-off and stormwater, animal waste, and maritime transport waste (Figure 28). Of these immediate causes, the two most important are municipal untreated sewage, and run-off and stormwater.

Immediate causes

There are a number of human pathogens (e.g. *Vibrio cholerae* and *Escherichia coli*) that can remain viable in raw wastewater and sewage. Direct discharges of municipal untreated effluent into rivers and the Lake directly contribute to microbiological pollution. These have contributed to the degradation of river and lake water quality for habitat and drinking use (Wandiga & Onyari 1987, Ntiba et al. 2001). The low standards of health in the region are caused by a general lack of awareness in good hygiene practices, direct contamination of beach waters through bathing and washing, and uncontrolled waste disposal around the shoreline (Karanja 2002). Reduction of the Biological Oxygen Demand (BOD) load of such effluent can significantly reduce the occurrence of water-borne diseases such as typhoid and cholera which are common in the Lake. Run-off and stormwater collect a lot of animal, plant and human waste from point and non-point sources and channel these to rivers and the Lake. Animal waste directly abets microbiological pollution of water by creating an environment that supports microbiological pathogens, while harbour and bilge discharges compound the microbiological pollution problem.

Sectors/activities

There are two major sectors from which the municipal untreated effluent is derived, i.e., agro-industry and urbanisation. Beer brewing, pulp and paper production, tanning, fish processing, agro-processing and abattoirs discharge raw/untreated waste to feeder rivers and lakes (e.g. Wandiga & Onyari 1987, Ntiba et al. 2001). The annual population growth is 2-4% in most parts of the Lake Basin but urban population growth is over 5-10% per year in most of the larger towns (Scheren et al. 2000). The number of people in urban population connected to sewerage systems are as shown in Table 25 (Scheren et al. 2000).

Table 25 Number of people in urban populations connected to sewerage systems in Lake Victoria Basin.

	Total population (1 000 people)	Urban population (1 000 people)		Number of towns
		Connected	Not connected	
Kenya	10 200	390	630	18
Uganda	5 600	210	870	9
Tanzania	5 200	27	340	4
Rwanda	5 900	ND	400	5
Burundi	2 800	ND	140	4
Total	29 700	627	2 380	40

Note: ND = No Data. (Source: Scheren et al. 2000)

An assessment of BOD_5 loading of Lake Victoria (corrected for purification in treatment plants, rivers and wetlands) shows that domestic pollution accounts for most of the BOD load, with the contribution of industry (mainly from breweries, sugar cane factories and soap and oil factories) being relatively low (Scheren et al. 2000). Kenya contributes a BOD load of 7 510 tonnes per year, Uganda contributes a BOD load of 4 540 tonnes per year while Tanzania contributes a BOD load of 3 920 tonnes per year (Scheren et al. 2000). 75% of the BOD load from Uganda originates from Kampala, while in Kenya, 50% of the BOD load originates from Kisumu (Scheren et al. 2000). Water hyacinth infestations have also been reported to lower the water quality in Kenya, Uganda and Tanzania (in terms of colour, pH, turbidity of water) and increase the treatment costs, particularly associated with keeping the water intake points free of water hyacinth (Mailu 2001).

There are several sectors that contribute to microbiological pollution of run-off and stormwater: these include the agriculture, urban, forestry and rural settlement sectors. Run-off and stormwater discharge are highest during the rainy seasons and consequent flooding is associated with increased incidence of water-related diseases.

There are two major sectors from which the animal waste is derived, i.e., agriculture (livestock) and wildlife. The large increase in livestock populations are exemplified in the trends for Nyanza province (Kenya), where in 1968 there were 988 571 cattle compared to 1 620 146 in 1991 (Kairu 2001). Within most of the communities, cattle are a source of wealth and status symbol so there is a tendency to keep large herds. Poor animal husbandry in cattle-keeping results in high animal waste load that can be reduced by zero-grazing methods. There are few ranches in the Basin due to the tsetse fly, and most of the herds are kept at subsistence levels following age-old traditions. Higher populations of wildlife during times of drought move towards watering points in the Basin, and there are also large hippo herds along the lake shore. Increased trade in the Lake Basin region has led to increased maritime transport, both human and in number of vessels plying the Lake, and hence larger quantities of harbour and bilge discharges.

Root causes

The treatment works in municipalities are either inadequate, using old and obsolete technology, have ageing components, or have simply ground to a halt (Table 26). They have also not been able to expand to keep pace with the increasingly larger populations. The municipal by-laws, such as those of Kisumu City, did not predict the growth and type of industries existing today, and so there is no capacity to manage the waste from these industries. Industries flout the by-laws and regulations as there is no monitoring and enforcement mechanism. Poor planning,

Table 26 Summary of the processes and actions behind the root causes of microbiological pollution.

Root causes	Sectors/ Activities	Immediate causes	Remarks
Economic	Agro-industry	Municipal untreated effluent	1. There is lack of economic incentives to encourage the industries to install clean technologies.
Technological (includes the notion of affordability)	Agro-industry	Municipal untreated effluent	1. Industries located within the municipalities have none, inadequate or dilapidated treatment facilities.
	Urbanisation	Municipal untreated effluent	1. There are inadequate and dilapidated treatment facilities in all three countries, so, for example, raw untreated sewage is pumped directly into the Lake e.g. in Kisumu. 2. There is poor sanitation infrastructure and poor waste disposal facilities in all settlements around the entire Lake.
	Urbanisation	Run-off and stormwater	1. There is poor waste management in urban settlements.
	Agro-industry	Run-off and stormwater	1. Poor animal husbandry and land management results in animal wastes being discharged in raw form into the waterways.
	Forestry	Run-off and stormwater	1. There is a lack of alternative energy sources, so deforestation takes place, and trees and bushes are cut down for woodfuel.
	Rural settlements	Run-off and stormwater	1. Poor sanitation infrastructure.
Legal	Agro-industry	Municipal untreated effluent	1. There is lack of compliance to operating standards in the industry.
	Urbanisation	Municipal untreated effluent	1. Outdated and inadequate regulations.
Governance	Agro-industry	Municipal untreated effluent	1. There is lack of monitoring and enforcement of existing legislation and regulations relating to effluent discharge from the industries.
	Urbanisation	Municipal untreated effluent	1. There is lack of enforcement of regulations. 2. Poor urban planning.
	Urbanisation	Run-off and stormwater	1. Poor urban planning. 2. Lack of monitoring and enforcement of waste disposal regulations.
	Rural Settlements	Run-off and stormwater	1. Lack of monitoring and enforcement of waste disposal regulations.
	Forestry	Run-off and stormwater	1. Lack of monitoring and enforcement of regulations governing the forestry sector.
Geographic	Agro-industry	Municipal untreated effluent	2. Industries are located close to the lake shore, discharging raw and untreated effluents in all three countries.
	Wildlife	Run-off and stormwater	1. High wildlife population close to or along the lake shore and generated waste leads to microbial contamination of the water.
Demographic	Urbanisation	Municipal untreated effluent	1. Increased rural-to-urban migration. 2. High-density of human populations.
	Agro-industry	Run-off and stormwater	1. High animal population in the Lake Victoria Basin generates a large amount of diffuse waste that finds its way into the waterways and lake.
	Wildlife	Run-off and stormwater	1. High wildlife population in the Lake Victoria Basin generates a large amount of diffuse waste that finds its way into the waterways and lake.
Environmental	Urbanisation	Run-off and stormwater	1. El Niño rains wash a lot of organic wastes into the waterways and the Lake.
	Agro-industry	Run-off and stormwater	1. El Niño rains wash a lot of organic wastes into the waterways and the Lake.

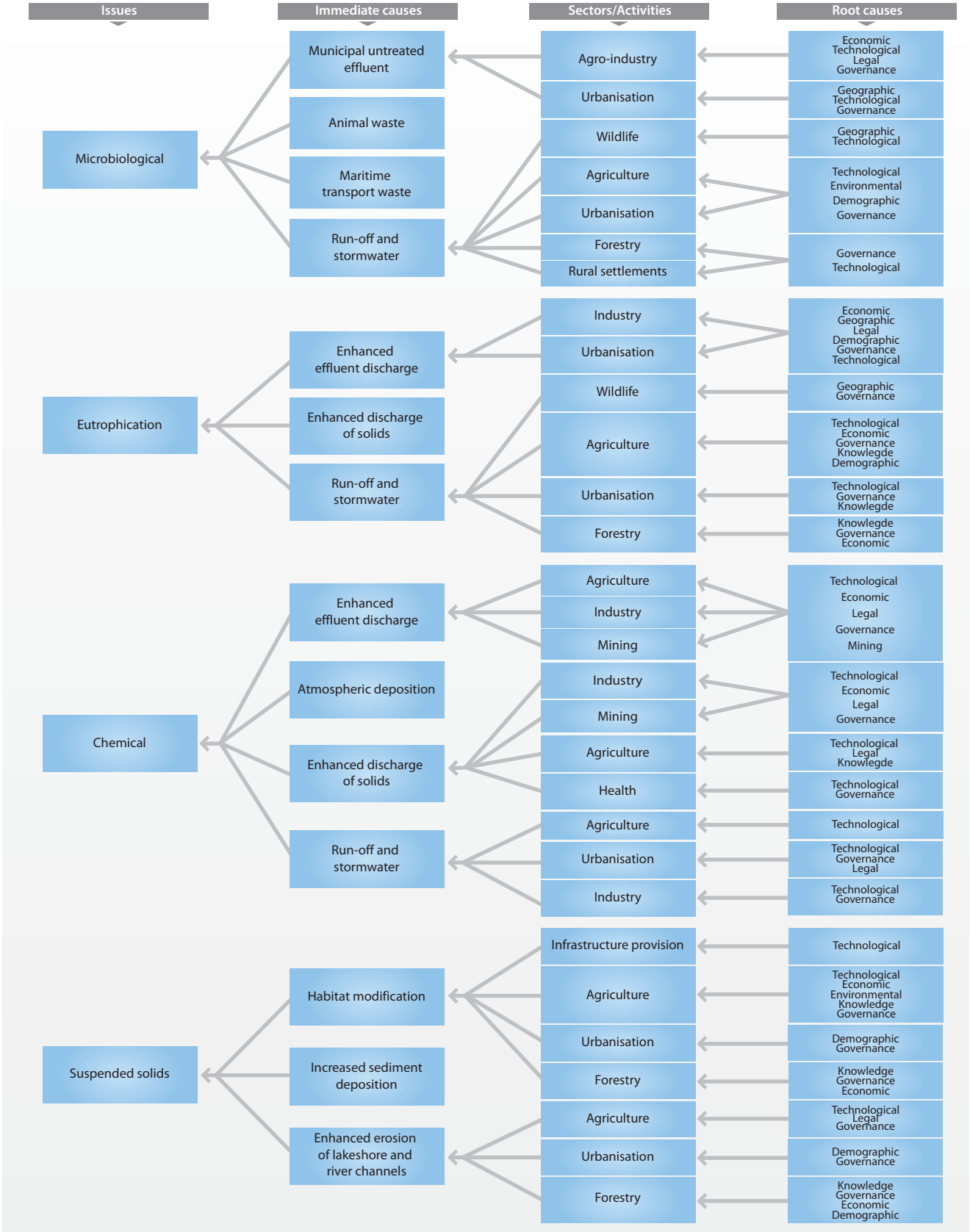


Figure 28 Causal chain diagram illustrating the causal links for Pollution

maintenance and inadequate investment in municipality wastewater treatment systems have contributed to the increased untreated effluent discharge. If the present treatment plants in Kisumu would perform optimally, the BOD loads could be brought down by 50% (Scheren et al. 2000). Water supply to both municipalities and villages is also affected by water hyacinth: in municipalities, water hyacinth interferes with the water intake points through blockage, which lowers the quantity of water pumped. In Kisumu the water supply has dropped from 20 000 m^3 to 10 000 m^3 per day (Mailu 2001). This decline in water supply invariably causes more people to look for alternative, and often untreated, water sources.

Flooding is common in the region, particularly around the lake shore, during the rainy season and its impact is exacerbated by poor practices when carrying out activities in the above sectors. Contamination of drinking water results from poor sanitation, hygiene and poor floodwater management. For example, there were 14 275 cholera admissions in Nyanza province (LVB Kenya) alone between June 1997 and March 1998, with 547 deaths reported (Karanja 2002). One of the major risk factors identified for cholera among a sample of these patients was drinking water from Lake Victoria or a stream (Karanja 2002).

The gross discharge of animal wastes into rivers and the Lake results from high livestock and wildlife populations within the Lake Victoria Basin, and poor animal husbandry and waste management. In Tanzania, however, the government is encouraging villagers to plan their land use to control livestock and game. Transport-related pollution (harbour and bilge discharges) are likely to become more important on the Lake as trade increases in the region (Cohen et al. 1996).

Eutrophication (and sedimentation)

Three immediate causes are identified for eutrophication; enhanced effluent discharge, run-off and stormwater, and enhanced discharge of solids (Figure 28). Enhanced effluent discharge, and run-off and stormwater are the most important immediate causes of eutrophication. The enhanced discharge of solids is largely a component of increased run-off and stormwater to the Lake and is therefore nested in this immediate cause.

Immediate causes

Analysis of sediment cores from the Lake show an increasing rate of sedimentation over the past 150 years (Swallow et al. 2002, Verschuren et al. 2002). There are many densely cultivated areas in the Lake Victoria Basin, especially in Kenya, Rwanda and Burundi (Scheren et al. 2000). Some rivers, such as the Sio, Nzoia, Yala, Sondu, Nyando and Kuja in the Lake Victoria Basin (Kenya) drain highly productive agricultural areas.

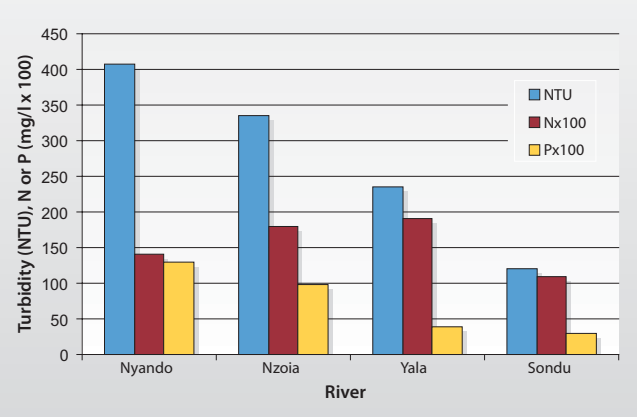


Figure 29 Comparison of turbidity, nitrogen and phosphorus levels of four Kenyan rivers, rainy season 2001.
(Source: Swallow et al. 2002)

The sediment load of the Nyando River, for example, has increased by 7.5 times during the last 16 years, with turbidity measured at 527 NTU in the rainy season 2001 (Figure 29) (Swallow et al. 2002).

Habitat modification through vegetation clearance for infrastructure provision, agriculture, urban settlements and the use of various plants for building materials, furniture making and fuel wood, etc., exposes the soil to erosion and deflation, thus contributing to increased suspended solids. Enhanced erosion of the lake shore and river channels is also directly contributing to increased suspended solids in the Lake. Soaps and detergents that are being used within the Basin are outdated or banned and are contributing to eutrophication. Analysis of nutrients (nitrogen and phosphorus) in the rainy season of 2001 in the Nyando, Sondu, Nzoia and Yala rivers indicates that continued addition of input of such high nutrient concentrations into the Winam Gulf will seriously affect aquatic systems and water quality (Figure 29) (Swallow et al. 2002). Nutrient loads to the Lake are associated mainly with atmospheric deposition and land run-off, together accounting for about 90% of the phosphorus and 94% of the nitrogen input into the Lake (Scheren et al. 2000).

Sectors/activities

The changes from small-scale to large-scale industrial production and from small to large farms have all contributed to enhanced effluent discharge. The acreage under cultivation for cash and food crops (namely tea, tobacco, rice, beans, coffee and sugar cane) in the Nyanza province, for example, has increased from about 15 400 ha in 1968 to 157 000 ha in 1991/1992 (Kairu 2001). The agricultural characteristics for the Lake Victoria Basin as a whole are as shown in Table 27.

Increased rates of urbanisation and agriculture in the region have increased the per capita demand for land (Kairu 2001), and hence more land is cleared to create the additional space required for these

Table 27 Agricultural characteristics of Lake Victoria Basin.

Country	Catchment land area (1 000 ha)		
	Cultivated	Non-cultivated	Total
Kenya	1 470	3 400	4 870
Uganda	1 400	2 100	3 500
Tanzania	1 500	5 540	7 040
Rwanda	930	1 130	2 060
Burundi	670	640	1 310
Total	5 970	12 810	18 780

(Source: Scheren et al. 2000)

sectors. There is, for example, large-scale draining of the Yala swamp (LVB Kenya) to create land for agriculture and settlement (Grabowsky & Poort 1987). Clearing of riparian vegetation has led to erosion and loss of vegetation that acted as filters (Lowe-McConnell 1994), while nutrient-rich sediments from agricultural run-off and also low-lying, deforested riparian zones and other areas surrounding the Lake contribute to eutrophication, and feed the carpets of water hyacinth (Wilson et al. 1999). During the process of the expansion and growth of agriculture, some wetlands have been drained (Kairu 2001, Gichuki 2003), leading to increased sediment deposition in the rivers and lake. The degree to which urban run-off and solid wastes contribute to suspended solids load has not been assessed (Ntiba 2003).

Root causes

There has been a lack of monitoring and enforcement of regulations (Table 28). Those industries that have tried to install recycling facilities in urban areas have not had support from the regulating authorities. The food and cash crops grown on wetlands require the application of fertilisers and pesticides (Kairu 2001). Unsustainable land use practices lead to increased soil erosion and nutrient land run-off (Scheren et al. 2000). The high atmospheric nutrient loads are attributed to forest burning and increased dust due to soil erosion (Bootsma & Hecky 1993). Sand harvesting activity is mainly performed 5-10 km away from the Lake, particularly in Winam and Ahero Divisions (LVB Kenya), but some sand harvesting is undertaken right on the shores of the Lake (Kairu 2001). This activity increases sediment mobility, and also results in physical alteration and destruction of the environment.

An important source of income is papyrus harvested for thatching houses and the making of mats, baskets, furniture (chairs), fishing floats, rafts, etc., while both shrubs and papyrus are used for wood fuel (Kairu 2001). There are farms, roads, fishing camps and housing developments close to or on the wetlands (Kairu 2001). Soil erosion in the wetlands is generally connected with cultivation, but specifically to farming methods and management (Kairu 2001).

Table 28 Summary of the processes and actions behind the root causes of eutrophication (and sedimentation).

Root causes	Sectors/ Activities	Immediate causes	Remarks
Economic	Industry Urbanisation	Enhanced effluent discharge	1. There is increasing growth in industries that generate effluents. 2. There are lack of economic incentives to encourage the industries to install clean technologies.
	Agriculture	Run-off and stormwater	1. There are lack of economic incentives to encourage proper management of farms etc.
	Forestry	Run-off and stormwater	1. Poverty is driving people to cut down vegetation cover for fuel wood, timber etc.
Technological (includes the notion of affordability)	Industry Urbanisation	Enhanced effluent discharge	1. There is a lack of clean technologies, e.g. recycling. 2. Poor sanitation. 3. Use of inappropriate or obsolete technology. 4. Inadequate treatment facilities.
	Urbanisation	Run-off and stormwater	1. There are poor or no waste disposal facilities. 2. There is poor waste management.
	Agriculture	Run-off and stormwater	1. Poor agricultural practices. 2. Use of agro-chemicals.
Legal	Industry Urbanisation	Enhanced effluent discharge	1. There is lack of compliance to regulations in the industries. 2. Poor standards that need to be updated.
Governance	Industry Urbanisation	Enhanced effluent discharge	1. There is lack of monitoring and enforcement of existing legislation and regulations relating to effluent discharge from the industries and urban settlements.
	Urbanisation	Run-off and stormwater	1. Government failure in provision of waste disposal facilities.
	Agriculture	Run-off and stormwater	1. No enforcement of regulations. 2. Lack of integrated knowledge and policy implementation (internal/external).
	Forestry	Run-off and stormwater	1. Lack of monitoring and enforcement of regulations governing the forestry sector.
Geographic	Industry Urbanisation	Enhanced effluent discharge	1. Industries are located close to the lake shore, discharging raw and untreated effluents in all three countries.
	Wildlife	Run-off and stormwater	1. High wildlife population generating unmanaged waste.
Demographic	Urbanisation	Enhanced effluent discharge	1. Increasing populations in urban areas.
	Agriculture	Run-off and stormwater	1. High livestock population in the Lake Victoria Basin generates a large amount of diffuse waste that finds its way into the waterways and lake. 2. Overstocking and over-grazing.
	Wildlife	Run-off and stormwater	1. High wildlife population in the Lake Victoria Basin generates a large amount of diffuse waste that finds its way into the waterways and lake. 2. Overstocking and over-grazing.
Knowledge	Agriculture	Run-off and stormwater	1. Lack of information, training and education, leading to over-grazing and overstocking. 2. Inadequate access to technical and scientific information. 3. Inadequate scientific understanding, e.g. replacement of traditional crops with commercial crops.
	Forestry	Run-off and stormwater	1. Lack of information, training and education e.g. on soil conservation. 2. Inadequate scientific understanding at the local level.

Chemical pollution

The identified immediate causes for chemical pollution are: enhanced effluent discharge, enhanced discharge of solids, run-off and stormwater, and atmospheric deposition (Figure 28). The latter is currently the least

important but, in terms of supply of nutrients such as nitrogen and phosphorus, it may become increasingly important as land use in the Basin and outside cumulatively reduces the vegetation cover, thus increasing the atmospheric load of fine particulate matter.

Immediate causes

Enhanced chemical effluent discharges go directly into the rivers and the Lake. Agro-chemicals used in agriculture contaminate the rivers and the Lake. Leachates from mining tailings that are close to the rivers or the lake shore, industrial wastes such as barley waste and chemicals are dumped into the Lake in a non-regulated manner. There is also disposal of expired pesticides, medical waste, petrol station wastes, bunkering wastes, etc. Some companies have stockpiles of banned substances such as DDT.

Sectors/activities

Most industry is located in the larger towns bordering the Lake; Kampala and Jinja in Uganda, Mwanza and Musoma in Tanzania, and Kisumu in Kenya, with the exception of the large sugar factories in Kenya located at some distance from the Lake (Scheren et al. 2000). Small-scale mining is increasing in parts of the Tanzanian catchment, leading to contamination of the waterways by mercury. There is a lack of incorporation of clean technologies in the industrial sector. For example, Panpaper Limited in Kenya (discharging into Nzoia River) could use an extra processing step of scrubbing technology to reduce SO_2 and produce sulphuric acid (added value product). Used chlorine has been dumped into the Lake killing a lot of aquatic organisms. In Uganda for example, expired chemicals as well as drugs and partially treated domestic sewage from Kampala area is dumped into public waterways, which finally end up in Lake Victoria (Kiremire 1997).

The use of agro-chemicals is increasing in the Lake Basin where there are large-scale farms of coffee, tea, cotton, rice maize, sugar and tobacco (Ntiba et al. 2001). The food and cash crops grown on wetlands require the application of fertilisers and pesticides (Kairu 2001). Much of Ugandan industrial effluents drain through wetlands before reaching the Lake surface water (Scheren et al. 2000). The urban and peri-urban growth is rapid and largely unplanned; many buildings are erected without authorisation, run-off rates are increased due to lack of stormwater drainages to handle urban run-off, and proper waste disposal is poorly or not at all co-ordinated by municipal authorities. Most of the poorly disposed urban wastes are then washed into water courses and eventually reach the Lake.

Root causes

In Tanzania and Uganda the industrial wastewater treatment facilities are generally absent, but in Kenya a majority of factories operate a

Table 29 Summary of the processes and actions behind the root causes of chemical pollution.

Root causes	Sector/ Activities	Immediate causes	Remarks
EconomicC	Agriculture Industry Mining	Enhanced effluent discharge	1. There is increasing growth in industries that generate effluents. 2. There are lack of economic incentives to encourage the industries to install clean technologies.
	Industry Mining	Enhanced discharge of solids	1. There is increasing growth in industries that generate effluents. 1. There are lack of economic incentives to encourage the industries to install clean technologies.
Technological	Agriculture Industry Mining	Enhanced effluent discharge	1. There is a lack of clean technologies. 2. Use of inappropriate, dilapidated or obsolete technology. 3. Inadequate treatment facilities.
	Agriculture Industry Mining Health	Enhanced discharge of solids	1. There is a lack of clean technologies. 2. Use of inappropriate, dilapidated or obsolete technology. 3. Inadequate or lack of treatment facilities. 4. There are poor or no waste disposal facilities, e.g. lack of proper disposal of food processing waste and lack of scientifically acceptable waste disposal from medical institutions.
	Agriculture	Run-off and stormwater	1. Use of agro-chemicals.
	Urbanisation	Run-off and stormwater	1. Lack of stormwater drainages.
Legal	Agriculture Industry Mining	Enhanced effluent discharge	1. Lack of compliance to regulations, e.g. improper disposal of chemicals used. 2. Non-regulation of the use of chemicals e.g. pesticides and fertiliser in the agriculture industry. 3. Poor standards that need to be updated.
	Agriculture Industry Mining	Enhanced discharge of solids	1. Lack of compliance to regulations, e.g. improper disposal of chemicals used. 2. Non-regulation of the use of chemicals e.g. pesticides and fertiliser in the agriculture industry. 3. Poor standards that need to be updated.
	Urbanisation	Run-off and stormwater	1. Lack of compliance to building codes.
Governance	Agriculture Industry Mining	Enhanced effluent discharge	1. There is lack of monitoring and enforcement of existing legislation and regulations relating to effluent discharge from the industries.
	Agriculture Industry Mining Health	Enhanced discharge of solids	1. There is lack of monitoring and enforcement of existing legislation and regulations relating to discharge of solids from the industries.
	Industry Urbanisation	Run-off and stormwater	1. Poor waste management in industry and urban areas. 2. Poor urban planning. 3. Lack of monitoring and enforcement of regulations in planning, design and structures development.
Geographic	Agriculture Industry Mining Health	Enhanced effluent discharge	1. Most of these industries are located close to rivers, and empty their waste into these rivers. Some are located along the Lake shoreline and discharge the waste directly into the Lake.
	Agriculture Industry Mining Health	Enhanced discharge of solids	1. Most of these industries are located close to rivers, and empty their waste into these rivers. Some are located along the Lake shoreline and discharge the waste directly into the Lake.
	Agriculture Industry Mining Health	Run-off and stormwater	1. Most of these industries are located close to rivers, and empty their waste into these rivers. Some are located along the Lake shoreline and discharge the waste directly into the Lake.
Knowledge	Agriculture	Enhanced discharge of solids	1. Lack of information, training and education, leading to misuse of pesticides and fertilisers.

treatment plant (Scheren et al. 2000). Some recent studies have shown that fish in Lake Victoria contain varying levels of organochlorine pesticide residues (Mitema & Gitau 1990), reflecting the transport of agro-chemical residues from farms within the catchment, through rivers to the Lake. Only a minority of industries are connected to an urban sewerage system (Scheren et al. 2000). Growth in industries has taken place against a backdrop of no infrastructure development for disposal of effluents. The currently existing sewage infrastructure has not been expanded or improved for decades. However, some of the industries are being allowed to establish their operations in areas that have been designated as "non-industrial", so they lack the infrastructure to handle their waste products. There is no enforcement of existing regulations regarding chemicals use and their disposal, and the current legislations are out-dated and in need of revision (Table 29). Lack of monitoring and poor scientific knowledge has led to the use of inappropriate or obsolete technologies to the detriment of the environment. The governments of the three riparian countries have taken no deliberate actions to put in capital resources to meet economic development needs.

Summary of the analysis

Although there are a large number of root causes identified in the Causal chain analysis, the specific factors relating to the various root causes are to a large extent similar and converge into only a few issues. These include: export markets for the fisheries; improvements in fish handling capacities and technologies used in the fisheries industry; the unrestricted access status of the Lake; lack of fishing quotas; lack of compliance to and enforcement of regulations and legislation governing the industries; weak regional integration of legal, institutional and implementing mechanisms; lack of involvement of stakeholders in decision-making processes; a low level of civic education and awareness at all levels; corruption; lack of cross-sectoral harmonisation of legislation in closely related industries; poor urban planning; use of old, dilapidated and inappropriate technologies; poor maintenance of treatment plants; lack of waste treatment and disposal mechanisms; poor agricultural/land use practices; poor standards for industrial operations; lack of incentives to industry to engage clean technologies; government failure in service provision; and, in most sectors, lack of resources and will on the part of the governments to mitigate the environmental problems.